JCAT Update
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Cadmium Alternative Studies for C-17 P^2 Projects

By:

Stephen P. Gaydos

March 16, 2005

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
16 MAR 2005		**00-00-2005 to 00-00-2005**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
Cadmium Alternative Studies for C-17 P2 Projects	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Boeing,P. O. Box 516,St. Louis,MO,63166**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES
25th Replacement of Hard Chrome and Cadmium Plating Program Review Meeting, March 15-17, 2005, Greensboro, NC. Sponsored by SERDP/ESTCP.

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**34**	

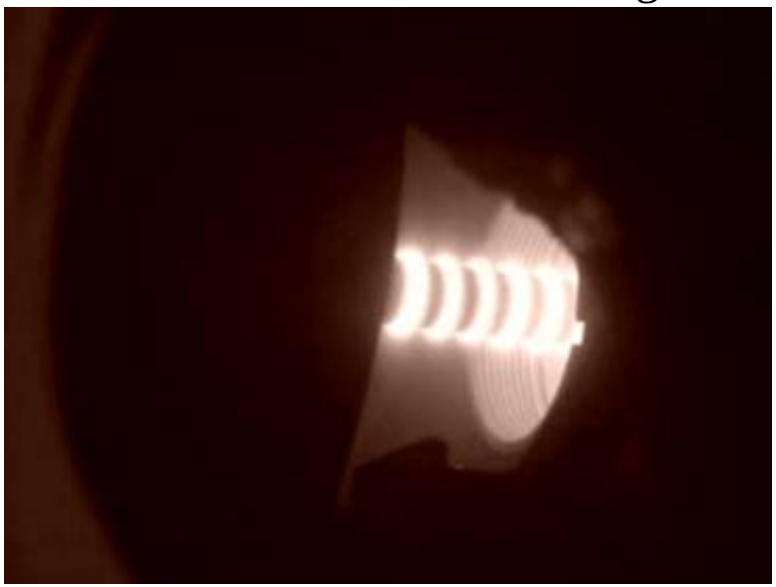
Qualification of Sputter Aluminum for C-17 Program

- C-17 MLG Axles Experiencing Corrosion on ID Surfaces
  - ID Finish is Currently Only Paint on Bare Steel
- Reduce or Eliminate ID Corrosion by Adding Sputter Aluminum Coating
  - OD Currently IVD Aluminum Coated
- Sputter Aluminum Technology Developed to Coat ID Surfaces and Work with IVD Coating Chambers (1998 - 2002)
  - Developed by Air Force, Boeing and Marshall Labs
  - Currently in Operation at Hill AFB

2002 Demo at Hill AFB for C-17 Program

C-17 Axle Before Coating

C-17 Axle Loaded on Coating Rack



Sputter Al Coating Applied on ID of Axle

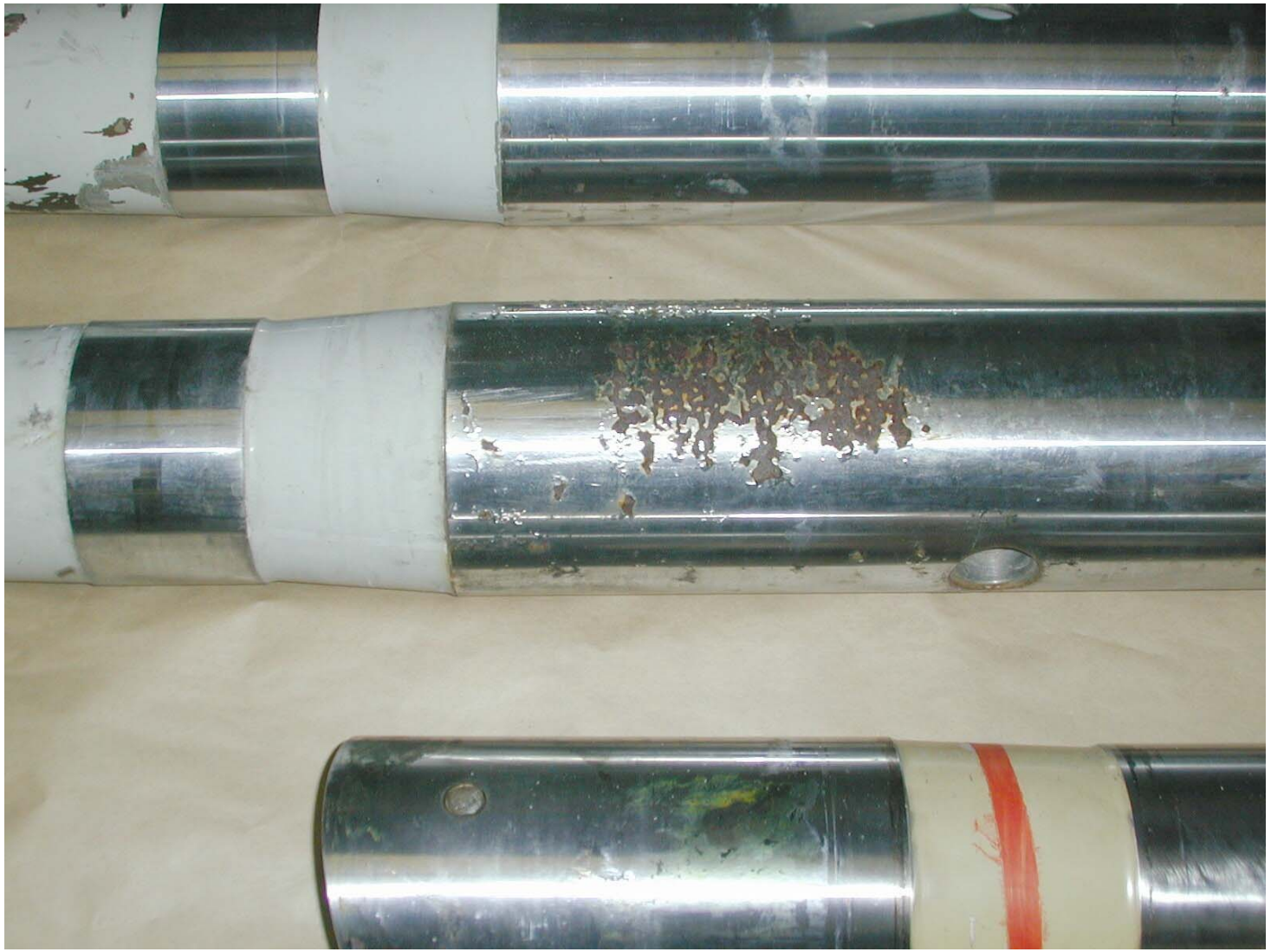
C-17 Axle After Coating – In Chamber

C-17 P2 Sputter Aluminum Project

- C-17 Program Convinced that Sputter Aluminum Could be Used to Coat ID of Axles
  - Axles Currently Having Corrosion Problem
- P2 Project Approved in 2003 to Qualify Sputter Aluminum for C-17 MLG Axles
  - Started October 2003
  - **Received Support from Hill AFB!**
  - Marshall Labs Contracted to Provide Tech Support
    - Also Coat HE Test Bars
  - Used Scrap C-17 Axles from Goodrich and Boeing

Hill AFB Coating Runs

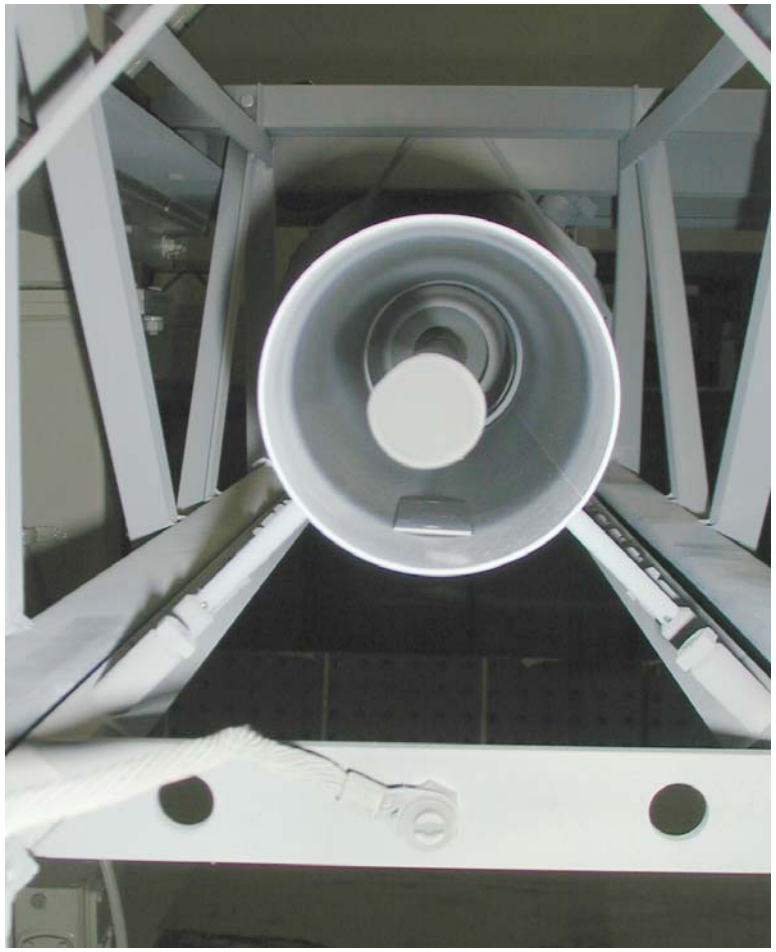
- Trip #1 – April 2004
  - Check Out Equipment and Make Sputter Runs
    - Verify Thickness and Prevent Overheating of 300M
      - Developed Procedures for Coating C-17 Axles
- Trip #2 – May 2004
  - Apply Sputter / IVD Aluminum Coat to Two Long C-17 Axles
- Trip #3 – June 2004
  - Apply Sputter / IVD Aluminum Coat to Two Short and One Long C-17 Axles
- Hill AFB Applied Conversion Coating and Paint
- Axles Shipped to Boeing – St. Louis (July 2004)



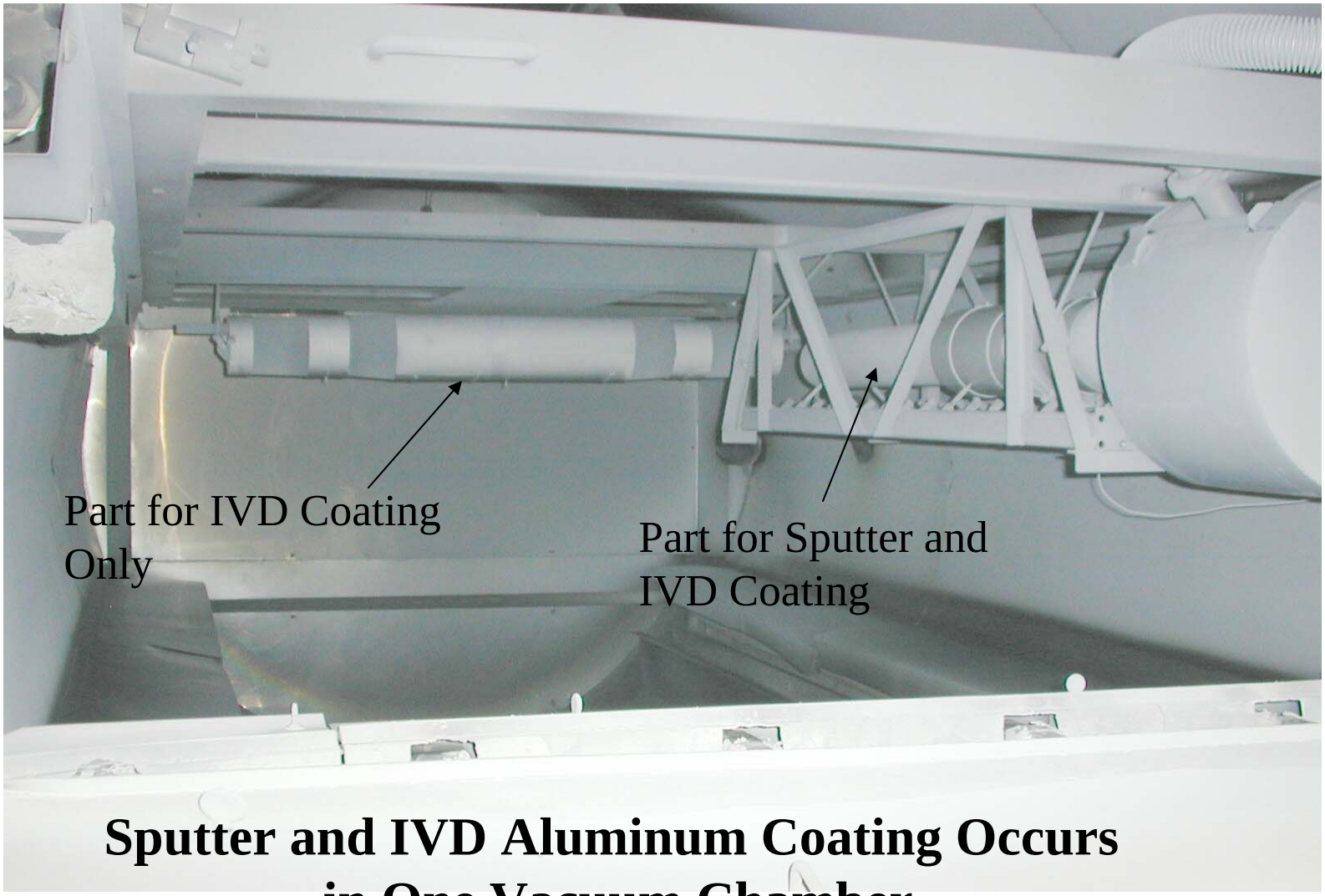
Scrap C-17 Axles Prior to Cleaning

C-17 Long Axle on Coating Rack

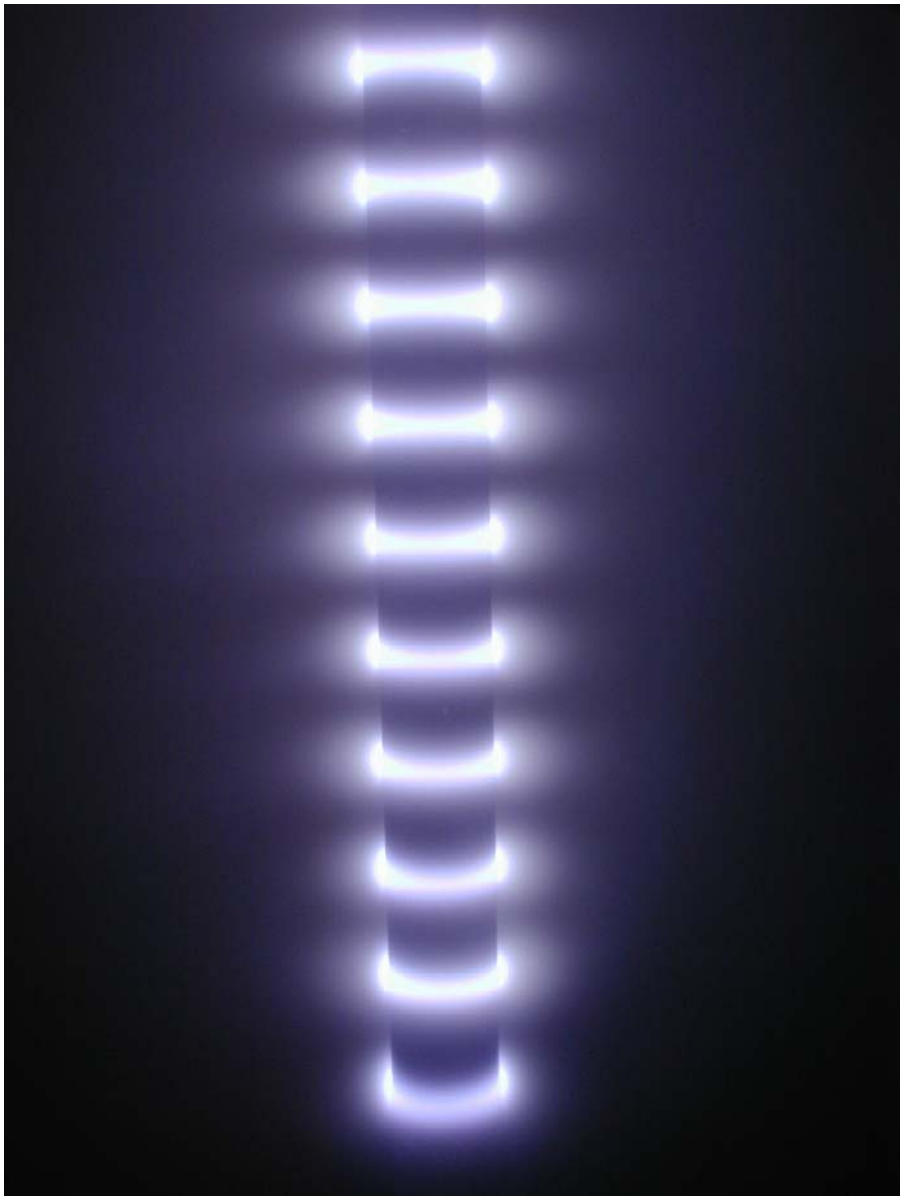
Long Aluminum Sputter Probe on IVD Rack



Sputter Probe Aligned In Center of Part



Sputter and IVD Aluminum Coating Occurs in One Vacuum Chamber

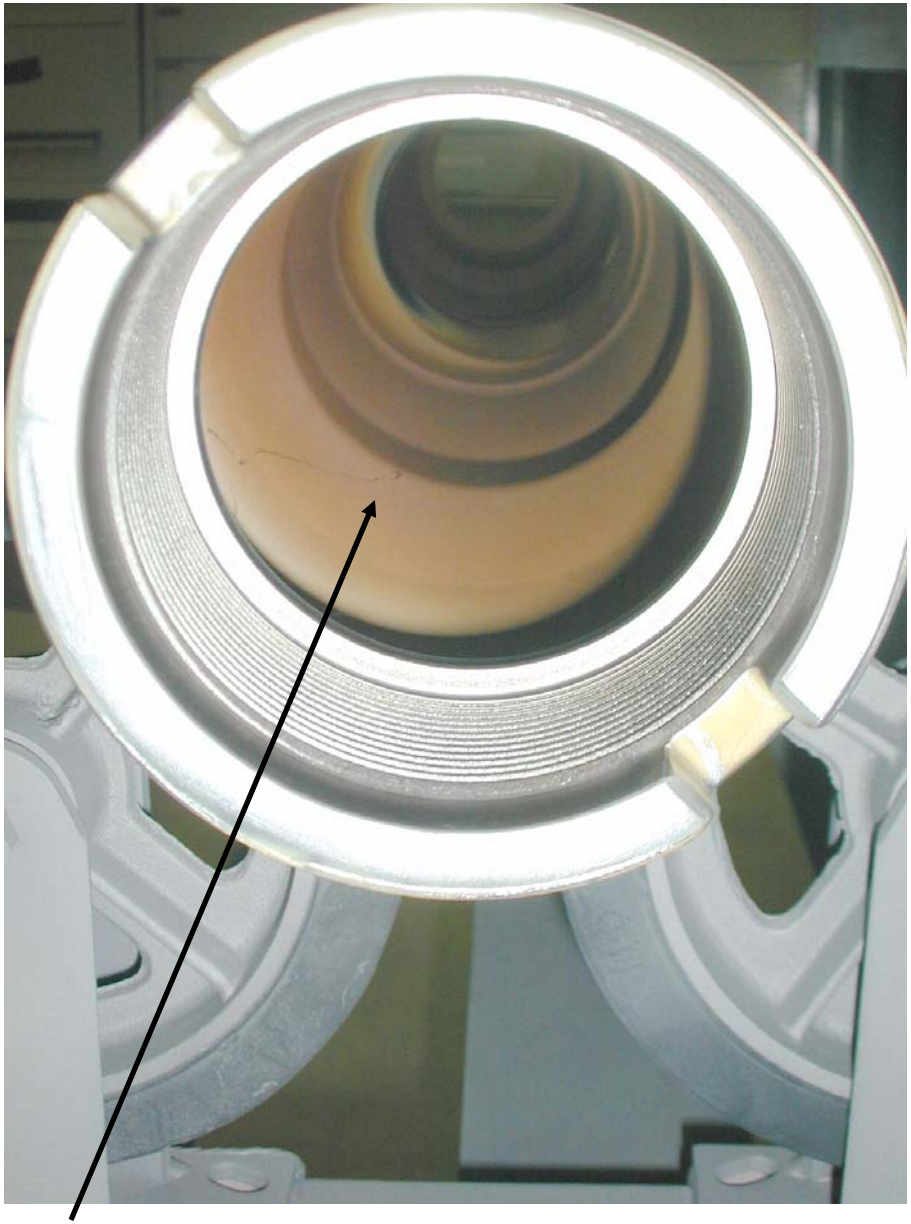


Sputter Probe Energized

View Inside Tube Showing Test Coupons for
Thickness and Adhesion Testing of Sputter Al Coating

C-17 Axle After Sputter / IVD Aluminum Coating

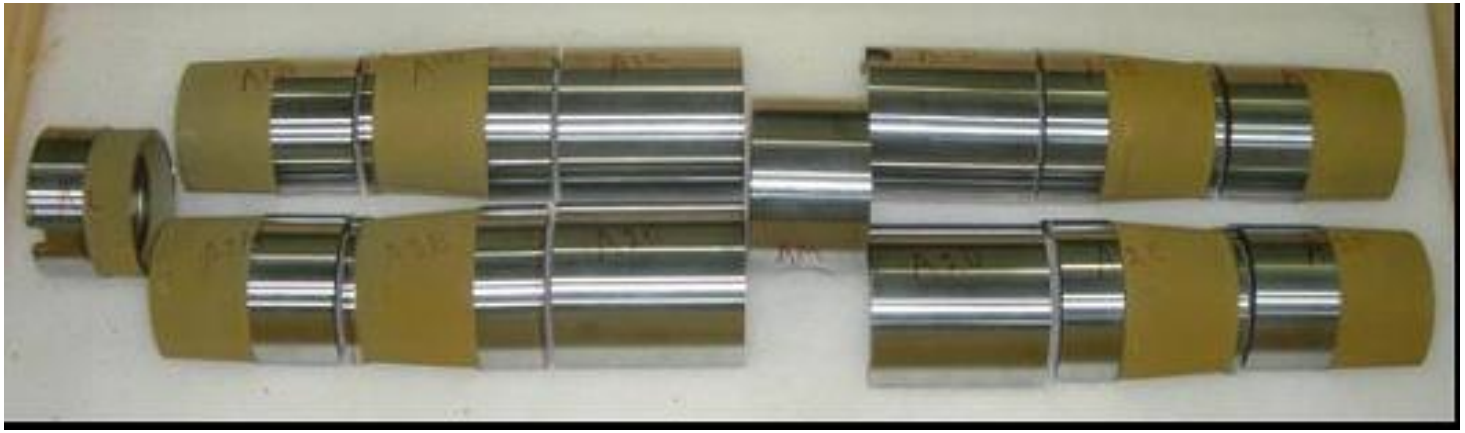
C-17 Axle After Conversion Coating

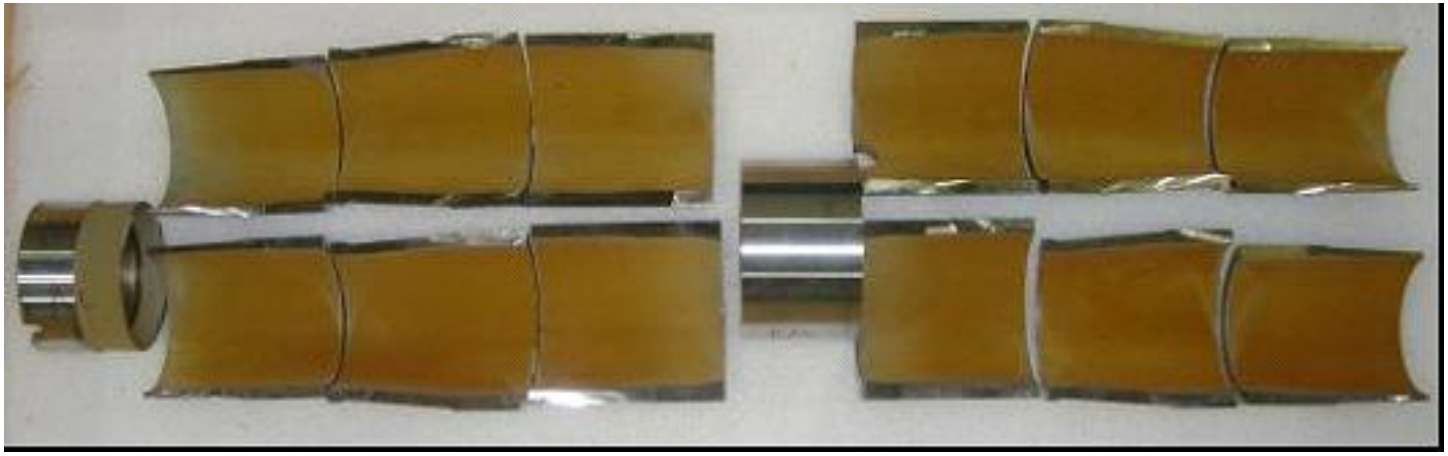


Conversion Coating On Sputter Aluminum Inside Axle

Evaluation of Axles at Boeing

- Initial Testing
  - Cut Up Axles Into 6” Tubes and Split Each Tube in Half (Along Length)
  - Check Thickness
    - Checked Sputter Aluminum and Paint Coatings
  - Check Adhesion
    - Adhesion of Sputter Aluminum to Steel
      - Tape Adhesion and Glass Bead Burnishing (20 - 80 psig)
    - Adhesion of Paint to Sputter Aluminum and Steel
      - Scribed Dry and Wet Tape Tests





C-17 Long MLG Axle Cut Into Test Specimens.

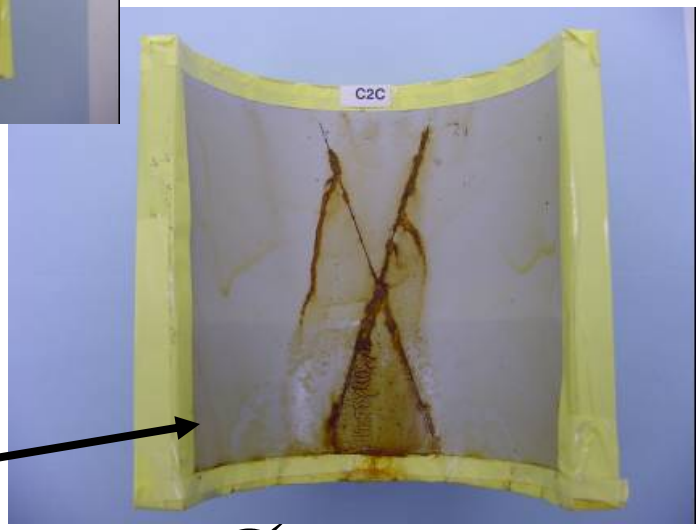
Top is OD and bottom is ID. Gold-brown areas are IVD aluminum (on the OD) and Sputter aluminum (on the ID) with conversion coating applied.

Corrosion Testing

- Axles B, C and D Subjected to Unscribed and Scribed Salt Spray (ASTM B 117)
  - B = Sputter Aluminum + Paint
  - C = Bare Steel + Paint + CPC
  - D = Sputter Aluminum Only
- ID Surface of Axles Tested for 1000 Hour Exposure

Sputter Aluminum + Primer + Polyurethane Topcoat – NO CORROSION!

Sputter Aluminum – White Corrosion



Bare Steel + Primer + Polyurethane + CPC – Red Rust!

MIL-DTL-83488 Requirements

- Sputter Aluminum Coating on C-17 Axles Met and Exceeded Requirements for Class 2, Type II
  - Thickness - 0.5 mil minimum
    - **Passed** – Sputter Coating was 0.7 to 1.0 mil
  - Adhesion – Burnish Till Shiny With No Flaking
    - **Passed** - Burnished at 80 psig With No Adhesion Problems
  - Paint Adhesion on Sputter Al – Wet Scribe Tape Test
    - **Passed** – No Adhesion Failures
  - Corrosion – Cl 2 , Ty II – 504 hours salt spray
    - **Passed** – Salt Spray Test Went to 1000 hours
      - No Red Rust - White Corrosion Products Were Minimal

Hydrogen Embrittlement Tests

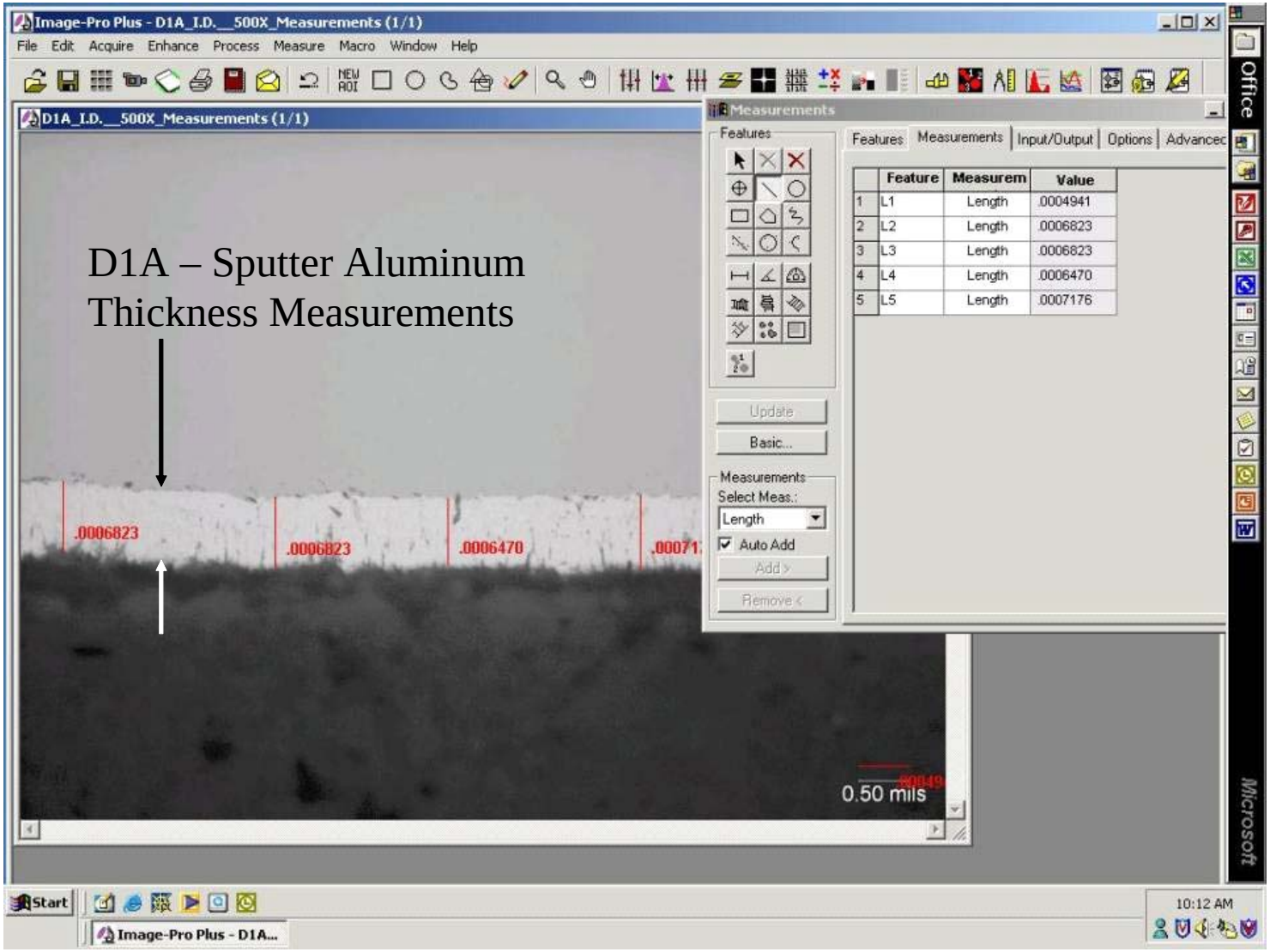
- Sputter Aluminum Application Process is Non-Embrittling
  - HE Testing and Baking Are Not Required
- Additional Tests Looked at Embrittlement Caused by the Environment for Sputter Aluminum and Steel
  - Tested in Distilled Water and 0.5% NaCl
    - Conducted Wet Notch Test @ 45% NFS x 150 hrs.
    - Different Coatings Applied to Sputter Aluminum and Bare Steel ASTM F 519 Type 1a.1 Specimens

Embrittlement Test Results

- Sputter Aluminum Needs a Coat of Epoxy Primer to Pass Sustained HE Test with Distilled Water
- Sputter Aluminum Needs Epoxy Primer and Polyurethane Topcoat to Pass Sustained Load Test with 0.5% NaCl
- Bare Steel Passed Distilled Water Test
- Steel with Primer Passed 0.5% NaCl Test

Microstructure

- Look at Microstructure of Sputter Aluminum
  - Metallography
  - SEM
- Check Thickness and Density of Sputter Aluminum
- Sputter Aluminum Typically Denser and More Uniform Than IVD Aluminum Coatings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File Edit Acquire Enhance Process Measure Macro Window Help
D1A_I.D.__500X_Measurements (1/1)
D1A – Sputter Aluminum
Thickness Measurements
.0006823
.0006823
.0006470
0.50 mils
Measurements
Features
Features Measurements Input/Output Options Advanced
Feature Measurem Value
1 L1 Length .0004941
2 L2 Length .0006823
3 L3 Length .0006823
4 L4 Length .0006470
5 L5 Length .0007176
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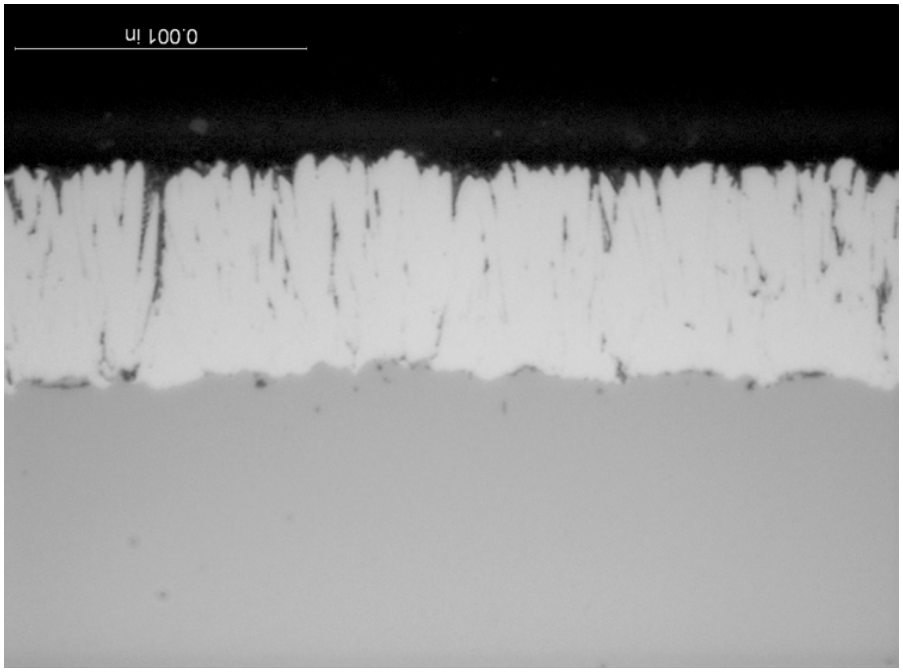
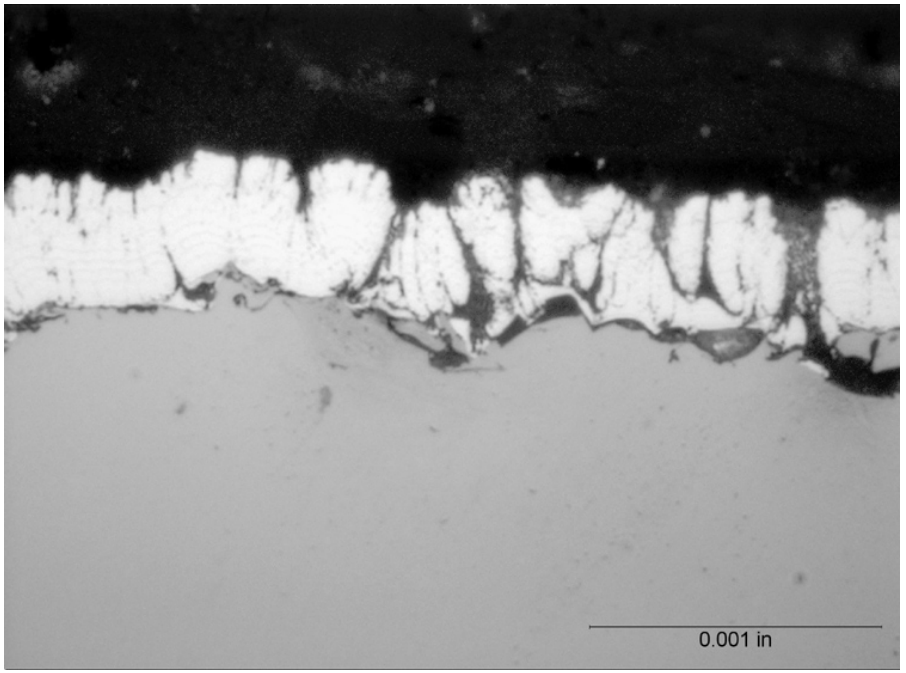


Sputter Aluminum



IVD Aluminum

Summary

- Hill AFB Equipment and Personnel Successfully Applied Class 2 Aluminum Coatings to C-17 Parts
  - Procedure Card and Process Specs Prepared to Document Process
- Sputter Aluminum Coating Meets MIL-DTL-83488, Class 2, Type II
- Sputter Aluminum with Primer and Polyurethane Provides Better Corrosion Resistance for the ID Surfaces of 300M Alloy Steel C-17 Axles

What's Next???

- Issue Qualification Report
- Issue DPS 9.22-1 for Sputter Aluminum
- Request Drawing Changes to Apply Sputter Aluminum to ID of C-17 Axles
- Certify Hill AFB to Apply IVD and Sputter Aluminum to Boeing Parts
  - Certify to DPS 9.22 (IVD) and DPS 9.22-1 (Sputter)
  - Meet Requirements in MIL-DTL-83488

Tank Plating Alternative - Alkaline Zn-Ni Plating

- Alkaline Zn-Ni Electroplating Looks Promising for Aerospace Applications
  - Easy to Use and Performance Similar to Cadmium
  - **BUT** - Needs Nickel Strike to Pass Hydrogen Embrittlement Tests
- Need an LHE Alkaline Zn-Ni
  - Similar to LHE Cd but with No Nickel Strike

LHE Alkaline Zn-Ni

- Develop and Evaluate LHE Alkaline Zn-Ni
  - Work with an Experienced Plating Vendor
- Evaluated Seven Potential Formulations
  - Corrosion (Scribed and Unscribed)
  - Thickness / Composition
  - Hydrogen Embrittlement
- Not All Zn-Ni Perform the Same Way
  - See Corrosion Test Results

Cd

LHE Alkaline Zn-Ni (Cont.)

- Hydrogen Embrittlement Testing
  - ASTM F 519
    - Type 1a.1, 1a.2
      - 200 hours at 75% NFS
    - Type 1e
      - ISL (Incremental Step Load)
- Two Alkaline Zn-Ni Formulations Pass HE Tests
  - Ni Strike with Zn-Ni (Formula #6)
  - LHE Zn-Ni Formula #7
- HE Tests Are Continuing

Brush Cadmium Plating Alternatives

- Cadmium Alternatives Evaluated for JG-PP Low Strength Steel Project
  - Zn-Ni
  - Sn-Zn
  - Zn-Sn
  - Others
- Zn-Ni Looked Good and was Described in the Low Strength Steel Joint Test Report

Brush LHE Cadmium Plating Alternatives

- Need Brush Cadmium Alternative Repair for High Strength Steels
  - No Bake after Plating!
    - Zn-Ni
    - Sn-Zn
    - Zn-Sn
    - Others
- Sn-Zn is Very Promising
  - Acceptable Corrosion and HE Performance
  - More Testing Required

After 672 Hours in Salt Spray